The comparison of different acoustic approaches in the simulation of human phonation

Jan Valášek*, Manfred Kaltenbacher† and Petr Sváček††

*,†† Department of Technical Mathematics
Faculty of Mechanical Engineering, CTU in Prague
Karlovo nam. 13, 121 35 Praha 2, Czech Republic
e-mail: jan.valasek1@fs.cvut.cz, petr.svacek@fs.cvut.cz

†Institute for Mechanics and Mechatronics
Technical University Vienna
Getreidemarkt 9, 1060 Wien, Austria
e-mail: manfred.kaltenbacher@tuwien.ac.at - Web page: http://www.mec.tuwien.ac.at

ABSTRACT

The physical modeling and numerical simulation of the human phonation is very complex topic of ongoing research. Its numerical simulation is of quite importance in medicine today, see, e.g. [5]. In this coupled problem the three different physical fields the deformation of the vocal folds (elastic body), the fluid flow and the acoustics have to be considered with all relevant coupling terms. Thereby, we consider the coupling between the fluid and the structure in a strong sense, whereas the acoustics filed is computed by a forward coupling from the fluid flow.

The two-dimensional physical model of fluid-structure interaction problem is described by linear elasticity theory and by incompressible Navier-Stokes equations. In order to enable the change of domain shape in time, the arbitrary Lagrangian-Eulerian method is used. The sound sources are calculated by the Lighthill analogy or evaluated from perturbation equations [4, 2].

The numerical model is based on the finite element method, which is used for all three physical domains. For stabilization of the fluid flow simulation, the modified Streamline-Upwind/Petrov-Galerkin stabilization is used, [1]. The perfectly matched layer with inverse mapping is applied for acoustic free-field simulation, see [3].

Finally, the comparison of numerical results obtained by Lighthill analogy and by perturbation equations will be presented.

REFERENCES

[1] T. Gelhard, G. Lube, M. A. Olshanskii, and J.-H. Starcke, *Stabilized finite element schemes with LBB-stable elements for incompressible flows*, Journal of Computational and Applied Mathematics **177**:2 (2005), 243–267.

[2] A. Hüppe and M. Kaltenbacher, *Spectral finite elements for computational aeroacoustics using acoustic perturbation equations*, Journal of Computational Acoustics **20**:02 (2012), 1240005.

[3] A. Hüppe and M. Kaltenbacher, *Stable matched layer for the acoustic conservation equations in the time domain*, Journal of Computational Acoustics **20**:01 (2012), 1250004.

[4] M. Kaltenbacher, M. Escobar, S. Becker, and I. Ali, *Numerical simulation of flow-induced noise using les/sas and lighthill's acoustic analogy*, International journal for numerical methods in fluids **63**:9 (2010), 1103–1122.

[5] R. Mittal, X. Zheng, R. Bhardwaj, J. H. Seo, Q. Xue, and S. Bielamowicz, *Toward a simulation-based tool for the treatment of vocal fold paralysis*, Frontiers in physiology **2** (2011), 19.